Fuel treatment effects on large fire suppression costs

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Motivation

- Cohesive Strategy goals:
  - Safe and effective response
    - Right place and time for suppression resources
  - Using wildland fire where appropriate
    - Feedbacks to future fire size, severity, and occurrence
    - Leveraging treated areas to support managed fire
- Direct and indirect benefits:
  - Restoration of active fire regimes
  - Reduce firefighter exposure
  - Reduced suppression expenditures?

Treatments, fire, and suppression costs

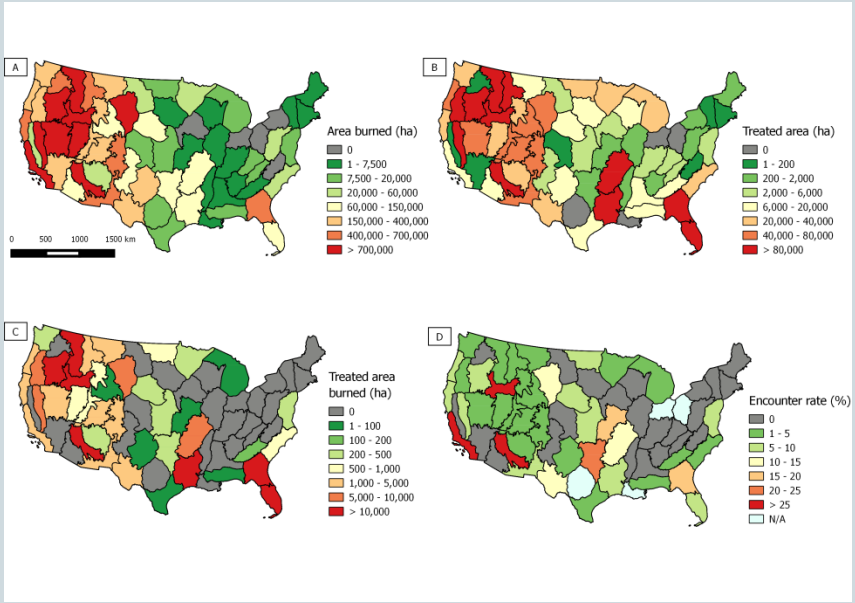
- Potential suppression cost savings due to fuel treatments
  - Changes in area burned (Thompson et al. 2013, Houtman et al. 2013)
  - Changes in burn severity (Fitch et al. 2013)
- Assume a causal link between driver and outcomes
  - Changes in management response?

Research questions and approach

- Do fuel treatments affect suppression costs on large fires?
  - Does this effect vary across ecoregions?
  - Does treatment type matter?
- Statistical relationship between costs and their drivers
  - Landscape characteristics
  - Incident Management Teams
  - Spatial distribution of treatments and previous fires

Methods

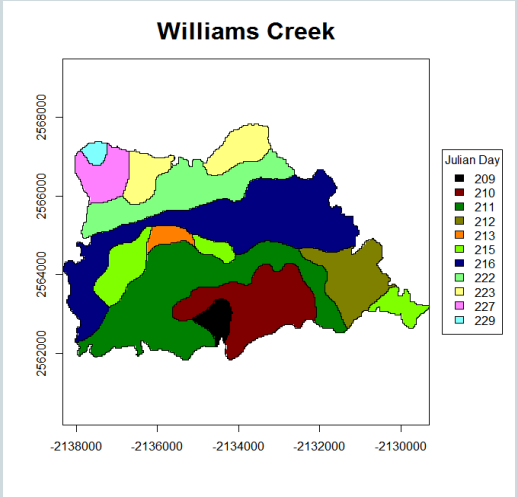
- Identify fires that burned into previous fuel treatments and/or fires
- Collect daily suppression cost data
- Characterize the daily fire environment
- Isolate fuel treatment effects using regression analysis

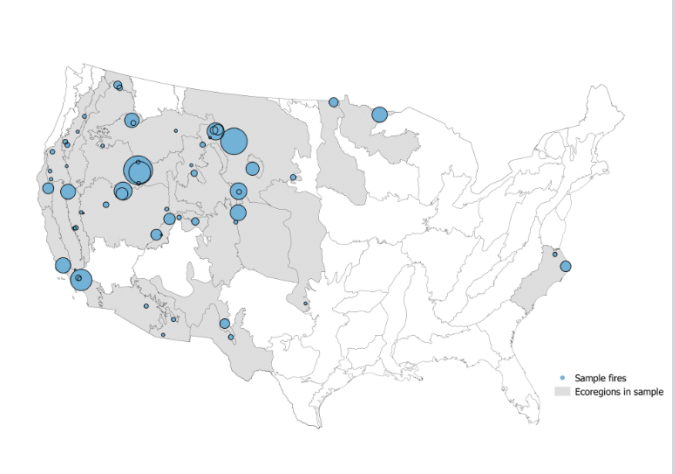


Barnett et al. 2016

Methods, cont.

- Fire and fuel treatment data
  - LANDFIRE treatment polygons (1999-2012)
  - MTBS fire polygons (1984 – 2014)
- Fire progression mapping
  - MODIS fire detection (Parks, 2014)
  - 30m resolution
- Daily FS suppression costs
  - I-Suite (Gude et al. 2013)
  - Type I or II IMT





Explanatory variables

Variable	Description	Units	Resolution
Climate, weather, fuels			
CMD	Hargreaves climatic moisture deficit	mm	1km
EREF	Hargreaves reference evapotranspiration	mm	1km
ERC	Available energy per unit area within the flaming front	percentiles	4km
NDVI	Index of vegetation productivity	dimensionless	30m
Land use			
POP_X	Total human population within a given buffer	persons	~90m
RDL_VOL	Product of road density and distance to roads	km^3	1km
WILD	Index capturing relative amount of protected areas	dimensionless	1km
Topography			
TPI	Topographic position index	dimensionless	30m
DISSECT	Dissection	dimensionless	30m
ERR	Elevation relief ratio	dimensionless	30m
Previous fuel treatments, fire			
RX	=1 if fire intersected previous fuel treatment	n/a	n/a
FIRE	=1 if fire intersected previous wildland fire	n/a	n/a

Econometric model

- Fixed effects

$$Cost_{ij} = \beta_0 FTreat_{ij} + \beta_1 X_{ij} + \alpha_i + \varepsilon_{ij}$$

α_i is the unknown intercept for each fire

ε_{ij} is the random error term

β_0 is a vector of estimated fuel treatment effects

- Random effects

$$Cost_{ij} = \beta_0 FTreat_{ij} + \beta_1 X_{ij} + \alpha_{} + (\varepsilon_{ij} + \theta ij)$$

- Fixed versus random?
  - Hausman test

Summary statistics

Variable	Mean	Std. Dev.	Min	Max
DAILY_COST	562,238	767,264	188	6,453,287
SPREAD_DAY	9.90	7.63	1	30
FIRE_AREA	283	2,615	0	53,006
FIRE_AREA_10k	17,328	29,201	0	205,522
RX_AREA	8.84	49.69	0	813
RX_AREA_10k	1,523	1,374	0	6,129
TPI_2km_sd	93	65	0.0507	243
POP_0	180	653	0	3,253
POP_10000	41,355	163,171	0	824,982
CMD	488	262.82	97.78	1,539
NDVI	0.46	0.14	0.146	0.69
WG_20k	0.18	0.19	0	0.74
AREA_BURNED	923	4,165	0	80,082
ERC	0.88	0.18	0.0235	0.9997
FIRE	0.18	0.38	0	1
RX	0.12	0.33	0	1

Results

Variable	RE
IMT_2	-0.251**
IMT_3	-1.35***
IMT_4	-2.75***
IMT_Local	-4.26***
IMT_UC	0.285**
TPI_2km_sd	0.028**
POP_0	0.00025***
CMD	0.00028
NDVI	1.19***
WG_20km	0.887**
ERC_mean	0.0163***
RX	0.385***
FIRE	0.241**
Time fixed effects	Yes
Fire-level random effects	Yes
R-squared	0.846
N	998
p < 0.01 *** , < 0.05 **, < 0.10 *	

Hausman test:
$\chi^2 = 84.5$, $p=0.29$

Results, cont.

Variable	Estimate
RX	0.434***
RX:LOW_POP	-0.178
FIRE	0.395***
FIRE:LOW_POP	-0.31*
Time fixed effects	Yes
Fire-level random effects	Yes
R-squared	0.846
N	998
p < 0.01 *** , < 0.05 **, < 0.10 *	

Results, cont.

Variable	Estimate
RX	0.514***
RX:LOW_RX	-0.271
FIRE	0.335***
FIRE:LOW_RX	-0.408**
Time fixed effects	Yes
Fire-level random effects	Yes
R-squared	0.847
N	998
p < 0.01 *** , < 0.05 **, < 0.10 *	

Results, cont.

Variable	Estimate
RX	0.620***
RX:EAST	-1.13***
RX:ROCKIES	-0.133
RX:WEST	-0.149
FIRE	0.078
FIRE:EAST	-0.291
FIRE:ROCKIES	-0.0184
FIRE:WEST	0.369
Time fixed effects	Yes
Fire-level random effects	No
R-squared	0.658
N	998
$p < 0.01$ *** , < 0.05 **, < 0.10 *	

Discussion

- Censored, not random sample of fires
  - I-Suite data only maintained for fires managed by a Type 1 or 2
  - Not evaluating passive management strategies
- Incomplete/imperfect fuel treatment data
  - Measurement error
- IMT captured substantial variability in daily cost
- Use of consistently derived geospatial layers
- Capturing fuel treatment effects is challenging
  - Time lags
  - At what point in a fire's progression does it encounter Rx?

Conclusion

- Preliminary results suggest:
  - Fuel treatment type (treatment vs. fire) influences outcomes
  - Different fuel treatment effects across broad ecoregions
  - Treatment effects vary according to population at risk
- Think carefully about expectations of fuel treatments
  - Integrating management of fuels with ignitions

Fire Name	Total cost	Average daily cost	No. of observations	Area burned within previous fire	Area burned within previous treatments	Proportion of days intersected by previous fire	Proportion of days intersected by previous treatment
BURBANK	1,645,508	329,102	5	0	3	0	0.2
DUMP	2,130,032	426,006	5	104	0	0.2	0
FRYE MESA	1,124,387	224,877	5	248	0	0.4	0
HOYT	1,256,288	251,258	5	3,223	0	0.6	0
INDIAN CREEK	1,425,814	285,163	5	2,508	0	0.4	0
POST	4,253,347	850,669	5	193	0	0.2	0
RAYMAY	2,017,348	403,470	5	0	0	0.2	0
CHUKKAR CANYON	308,557	51,426	6	7,019	0	0.67	0
INDIAHOMA WYE	585,603	97,601	6	28	50	0.33	0.33
DAHL	2,539,456	362,779	7	1,220	0	0.43	0
KINYON ROAD	1,763,493	251,928	7	62,315	140	0.43	0.43
MOTOR	7,742,799	1,106,114	7	1,779	48	0.43	0.43
SAYRE	16,138,443	2,305,492	7	1,677	9	0.29	0.14
SILVIES RIVER	2,516,033	359,433	7	0	619	0	0.29
CANELO	1,472,134	184,017	8	1,182	0	0.12	0
ETHAN	923,721	115,465	8	11	0	0.38	0
SCOTT MOUNTAIN	3,150,122	393,765	8	0	10	0	0.12
WOLF DEN	2,112,641	264,080	8	3	0	0.12	0
DELPHIA	2,517,298	279,700	9	4,236	0	0.33	0
DUNN MTN. ASSIST	889,615	98,846	9	24,444	0	0.56	0
LONG BUTTE	3,952,131	439,126	9	93,563	102	0.33	0.22
OIL CREEK	5,194,707	577,190	9	0	6	0	0.11
FOURMILE CANYON	9,381,855	938,186	10	11	72	0.1	0.1
TENNANT	4,244,837	424,484	10	0	72	0	0.2
BOX CREEK	3,094,647	281,332	11	97	0	0.18	0
CACTUS MOUNTAIN	1,841,717	167,429	11	2,302	0	0.27	0
COW CAMP	2,725,087	247,735	11	1,150	0	0.18	0
NINETEEN MILE	3,793,777	344,889	11	0	33	0	0.09
WOOD HOLLOW	6,031,414	548,310	11	1,738	0	0.18	0
BUFFALO LAKE ROAD	1,790,555	137,735	13	1,362	0	0.15	0
COLUMBIA RIVER ROAD	8,487,395	652,877	13	2,236	0	0.23	0
JUNEBERRY 3	1,450,664	111,590	13	3,970	0	0.15	0
MAYHILL	4,028,368	309,874	13	675	574	0.15	0.31
CHURCH CAMP	5,241,626	374,402	14	14	0	0.07	0
ARAPAHO	12,701,507	846,767	15	4,820	18	0.47	0.07
NEW FORK	2,769,204	162,894	17	0	255	0	0.12
BOZE	6,456,792	358,711	18	4	20	0.11	0.22
BIG MEADOW	16,290,924	857,417	19	1,818	65	0.37	0.16
BACKBONE	16,897,775	844,889	20	1,902	0	0.35	0
WILLIAMS CREEK	14,482,527	724,126	20	0	85	0	0.25
HIGH PARK	38,878,306	1,690,361	23	233	9	0.22	0.13
OAK FLAT	17,006,841	739,428	23	26	0	0.13	0
LATERAL WEST	9,063,303	362,532	25	2,140	330	0.28	0.2
ASH CREEK	7,555,005	279,815	27	18,288	1,031	0.3	0.15
DOLLAR LAKE	14,727,394	525,978	28	34	0	0.14	0
NORTH PASS	29,976,215	1,070,579	28	0	25	0	0.14
CHIPS	39,586,617	1,365,056	29	10,545	857	0.86	0.55
CACHE CREEK	11,463,880	369,803	31	23,846	0	0.48	0
CASCADE	8,758,723	250,249	35	0	120	0	0.17
STATION	93,416,145	2,395,286	39	779	956	0.05	0.21
LA BREA	34,508,265	821,625	42	1,251	1,645	0.14	0.17
PAINS BAY	12,029,858	273,406	44	823	819	0.18	0.18
PAGAMI CREEK	21,630,584	470,230	46	155	73	0.04	0.04
STAFFORD	11,531,945	230,639	50	0	138	0	0.06
TWITCHELL CANYON	16,269,980	280,517	58	0	538	0	0.17
SOUTH 1	9,918,851	150,286	66	169	246	0.03	0.11